Mechanical properties of triclosan sutures

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DOI: https://doi.org/10.1002/jor.23814

Originally published at:
Jungwirth-Weinberger, Anna; Grubhofer, Florian; Imam, Mohamed A; Bachmann, E; Wirth, Stephan (2018). Mechanical properties of triclosan sutures. Journal of Orthopaedic Research, 36(6):1777-1782.
DOI: https://doi.org/10.1002/jor.23814

Research Article

Mechanical Properties Of Triclosan Sutures[†]

Running title: Mechanical Properties Of Triclosan Sutures

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None of the authors have any competing interests.

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[†]This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: [10.1002/jor.23814]

Received 22 August 2017; Revised 28 October 2017; Accepted 18 November 2017
Journal of Orthopaedic Research

DOI 10.1002/jor.23814

Abstract

To avoid infections and wound healing disorders Triclosan coated sutures have been invented. Little is known of these sutures regarding their tensile properties. Three different Triclosan coated sutures (Vicryl 1 plus, PDS 0 plus, Monocryl 3-0 plus) were tested at several time points over 42 days regarding load to failure, strain and stiffness compared to their non-coated versions (Vicryl 1, PDS 0, Monocryl 3-0). Four different measurement points were made. Suture loops were fixed in a material testing machine over two metal bars which were moved apart creating a stress to the fiber. Unpaired, two-tailed t-test were performed for each group (untreated and treated) while level of significance was defined at a level of P<0.05. Vicryl 1 was significantly stronger on day 14 than Vicryl 1 plus (p=0.033). On day 28 significant changes were found in PDS 0 which was weaker compared to PDS 0 plus (p=0.039) and Vicryl 1 which was stronger than Vicryl 1 plus (p=0.032).

We have seen that Vicryl 1 plus sutures are significantly weaker according to loading to failure after 14 and 28 days, which might cause incisional hernias. PDS 0 sutures are used to reconstruct tendons, therefore a longer durableness might be of interest as re-ruptures of tendons are problematic. Our in vitro findings support the use of Triclosan coated PDS plus sutures and Vicryl sutures as they show a longer resistance. This article is protected by copyright. All rights reserved

Keywords

Suture, Material properties, Degradation, In vitro, Orthopaedic surgery, Triclosan

Background

Suture material is imperative to hold position of tissue until healing has been achieved [1]. Triclosan coated sutures were introduced into orthopaedic surgery with the aim of decreasing the risk of infection and other wound healing problems. Additionally, another medically useful advantage is that they can reduce periprosthetic infections in joint replacement surgery which is a drastic complication associated with increased pain, morbidity, and mortality [2]. Triclosan is an antimicrobial substance that reduces wound infections [3-7].

Triclosan is a broad a broad-spectrum antiseptic agent, more effective against gram-positive species as Staphylococcus aureus, Staphylococcus epidermidis, Methicillin-resistant Staphyloccocus aureus and Staphylococcus epidermidis than gram-negative species [8]. Barbolt [9] evaluated the safety of Triclosan and found no evidence of carcinogenic, teratogenic or genotoxic potential.

In our review of the literature it has been shown that there are no studies about tensile properties of Triclosan coated sutures such as the load to failure, strain at maximal load and stiffness compared to their non-coated versions. Also no effects of Triclosan on other materials are reported. The knowledge of the effect of Triclosan is particularly important in orthopaedic surgery as the suture material is exposed to substantial mechanical loads for a prolonged interval of time such as in cases of tendon or ligament healing.

It was the purpose of this biomechanical analysis to investigate the stability and mechanical strain of triclosan coated sutures in comparison to non-coated suture material. Data on mechanical strength of sutures is normally available from the sutures manufacture but has not yet been reported in this case. We hypothesized that the mechanical properties of Triclosan coated sutures mechanical would be dependent on the manufacturing material used and would demonstrate different mechanical properties when compared to non-coated suture material.

Methods

Basic studies

We utilized and tested three different absorbable suture materials, which are commonly used in orthopedic surgery. All the sutures are manufactured by Johnson&Johnson. The company was informed about the study and gave their consent.

All three different absorbable sutures were tested at four points of time (Table 1). The needle was initially removed from the suture for the testing purposes. The loops were circled around a metallic cylinder (40mm in diameter) at day 1 (Fig. 1) and tested with regard to load to failure, strain at maximal load and stiffness. All knots were tied in the same manner in a single button technique with 5 knots.

All sutures were incubated together in groups in a polyethylene tube containing 50 ml of a standard testing solution for absorbable materials (Dulbecco's Phosphate Buffered Saline, Sigma-Aldrich, USA). All tubes were kept at a constant temperature of 37.0 ± 1 degree (Celsius). The pH of the solution was buffered to 7.4 ± 0.2 for the whole time of incubation (Fig. 2). Stress tests were performed at four different points of incubation. These included Point 1 representing day 1 without incubation; Point 2 after 14 days, Point 3 after 28 days and Point 4 after 42 days. Measurements on five loops were made for load to failure for each material and at each time point and on five loops for strain and stiffness. Load to failure was defined as tear of the suture. The loops were fixed over two metal bars in a material testing machine Zwick010 (Zwick/Roell, Zwick GmbH, Germany). The loops were moved apart by the machine creating a stress to the fiber (Fig. 3). Grip to grip separation at start was 40mm. Using the first five loops of each suture, load to failure with a testing speed of 10 mm/s was recorded after a preload of 1 N was reached. With the second five loops of each suture the material of the sutures was evaluated under repetitive load. Thereby, 30 cycles from 1 N to 50% of the previously recorded force to failure were applied with a position controlled testing speed of 2 mm/s (10). After cyclic loading, a single-cycle load-to-failure test was conducted with a cross head speed of 10 mm/s. Data was recorded using TestXpert II software

(Zwick/Roell, Zwick GmbH, Germany) and evaluated on a the basis of a load-displacement curve. The load to failure measured in Newton (N) was the primary endpoint. The stiffness (Newton / millimeter) and strain after cycling loading (%) were the secondary outcome parameters. No failure of knots were reported, all the sutures ruptured at the loop.

Statistical analysis:

Statistical evaluation was done with standard statistical software (Prism 7, GraphPad, La Jolla, CA). Sample size was justified based on the number in a similar study from Müller et al. [1]. Presented data, used for statistical evaluation was tested on normal distribution with the Anderson-Darling test. Unpaired, two-tailed Student t-test were performed for each group (untreated and treated) while level of significance was defined at a level of $P<0.05$. Descriptive analyses for categorical variables are given in frequencies with the according percentages. Recorded values are indicated as mean with their standard deviation (mean ±SD).

Results

Load to failure

On day 0, without incubation, PDS 0 vs PDS 0 plus, Vicryl 1 vs Vicryl 1 plus and Monocryl 3-0 vs Monocryl 3-0 plus showed no significant difference.

The load to failure improved at day 14 after incubation in PDS 0 and PDS 0 plus to 96.7N in PDS 0 and 96.36N in PDS 0 plus. Significant changes in load to failure could be found on day 14 in Vicryl 1 with a mean of 128.8N ±7.6N compared to Vicryl 1 plus with 113 ±9.6N (p=0.033). Monocroyl 3-0 vs. Monocryl 3-0 plus did not show significant changes on day 14. Statistic evaluation of Monocryl 3-0 and Monocryl 3-0 plus on day 28 and 42 was not possible due to the degradation and decay of the suture.

The development of load to failure showed decrease of strength in all sutures after day 14. On day 28, significant changes were found in PDS 0 (85.3 ±5.2N), compared to PDS 0 plus (94.7 ±5.3N, p=0.039) and Vicryl 1 (54.5 ±8.0N) compared to Vicryl 1 plus (42.9N, p=0.032). Differences on day 42 were not significant in PDS 0 and PDS 0 plus, and Vicryl 1 and Vicryl 1 plus. (Fig. 4)

Stiffness

On day 0, Vicryl 1 (24.6 ±0.87N/mm) was significantly stiffer than Vicryl 1 plus (21.2 ±1.58N/mm ; p=0.0114). Monocryl 3-0 (4.3 ±0.08N/mm) was significantly less stiff than Monocryl 3-0 plus (4.6 ±0.15N/mm ; p=0.0127). On day 0 and day 14, the differences in PDS 0 and PDS 0 plus were not significantly. Significant changes again could be found on day 14 in Vicryl 1 (26.1 ±1.29N/mm) compared to Vicryl 1 plus (23.9 ±0.48N/mm; p=0.013). Monocryl 3-0 and Monocryl 3-0 plus showed similar insignificant different results on day 14. Monocryl 3-0, Monocryl 3-0 plus, Vicryl 1 and Vicryl 1 plus were not evaluated on days 28 and 42 because not enough samples were available because of decay of those sutures.

On day 28, PDS 0 retained stiffness of 6.18 ±0.39N/mm just like PDS 0 plus with a mean of 6.7 ±0.18N/mm. On day 42, there were a mean of 6.7 ±0.39N/mm in PDS 0 and a mean of 6.9 ±0.19 N/mm in PDS 0 plus. (Fig. 5, Table 2).

Strain after cycling loading

Strain after cycling loading did not show significant changes in all sutures over time.

On day 0, PDS 0 showed a strain of 6.5 ±2.47%, compared to 5.8 ±1.56% in PDS 0 plus.

On Day 0, Vicryl 1 showed a strain of 11.3 ±0.91%, those of Vicryl 1 plus was 10.4 ±1.29%. Strain of Monocryl 3-0 was 6.9 ±0.77%, compared to 7.3 ±0.56% in Monocryl 3-0 plus on day 0.

On day 14, PDS 0, PDS 0 plus, Vicryl 1, Vicryl 1, Monocryl 3-0 and Monocryl 3-0 plus showed a strain of 5.2 ±0.52%, 6.1 ±1.04%, 13.4 ±0.33%, 13.9 ±0.33% , 14.1 ±0.63% and 13.46 ±2.58% respectively.

On day 28 and 42 again merely results of PDS 0 and PDS 0 plus were present due to degradation of Monocryl and Vicryl sutures. None of the Monocryl 3-0 and Monocryl 3-0 plus suture was available on day 28 and 42 for testing of strain. On day 28 one Vicryl 1 suture and one Vicryl 1 plus suture remained. None of the Vicryl 1 and Vicryl 1-0 suture was available on day 42.

PDS 0`s strain on day 28 was 6.4 ±0.88% compared to 6.7 ±0.52% in PDS 0 plus. On day 42, PDS 0`s strain was 10 ±2.81% compared to 9.9 ±0.49% in PDS 0 plus. (Fig. 6, Table 3)

Discussion

It was the purpose of this study to investigate if Triclosan has an effect on the suture´s strength. We found that Vicryl 1 plus sutures are significantly weaker, with regard to the loading to failure force after 14 (-12.3% of strength of Vicryl 1) and 28 days (-21.3%) compared to Vicryl 1 sutures in our study (Table 4). Why the coating of the suture changes the biomechanical property of the suture remains unknown. No effects of Triclosan on materials are reported in the literature. There may be a physical or chemical influence of Triclosan on the surface and structure of the sutures. Further studies including microscopy/microanalysis are needed.

As far as we know, this is the first study comparing mechanical properties of Triclosan coated sutures to their non -coated version. Other studies in the literature concentrate on the antimicrobial effect of Triclosan and the decrease of surgical site infection and not on their tensile properties.

Storch et al [10] compared Vicryl plus sutures to Vicryl sutures and found no effect in physical properties. The sutures were evaluated by surgeons after testing the sutures in vivo in porcine models. No difference in knot tie-down and handling, breaking strength retention and absorption was found. Intraoperative handling was also discussed by Ford et al (11) showing no significant difference between Triclosan coated suture and the traditional one. They also compared the incidence of postoperative pain which was significantly less in patients treated with Triclosan coated sutures. They assumed that pain is an indicator of subclinical infection when using non-coated sutures.

Vicryl suture material is used to close and stabilize subcutaneous or deeper fascial layers (7), a less resistant Vicryl suture plus material might cause incisional hernias, which might require a second surgery [12]. After incubation, slight differences were observed between the two groups. Significant changes in load to failure were shown in Vicryl 1 and Vicryl 1 plus after 14 and 28 days. In contrast to Vicryl 1 plus, PDS 0 plus sutures showed statistically higher load to failure forces compared to the non-coated PDS 0 suture 28 day after incubation (10%). In orthopaedic surgery, PDS 0 sutures are used to reinforce or reconstruct tendons, therefore a longer durability of this suture material might be of interest as re-ruptures of tendons are unwanted complications and should be avoided. In cases of tendon repairs the main aim is to surgically position and fix the tendon in anatomical position using suture material that is strong enough to resist failure under repetitive loading. There are forces produced by repetitive loading on the repair site. This can consequently endanger proper healing especially in the event of failure of the suture itself, which is common. These are crucial parameters that should be taken into consideration whenever the surgeon is choosing the suitable suture material. Important variables that should be considered include the suture material ability to resist the load bearing capacity.

A limitation of the study, which is the main concern in similar biomechanical studies, is that the analysis has been undertaken in an in vitro condition, which is different to the in vivo environment. Although it was tried to simulate an in vivo situation, this could not be entirely reproduced. Also, the setting may not be applied to the in vivo situation in regards to load and strain.

Further studies in vivo are necessary to prove our in vitro findings and identify the effect of Triclosan sutures on resistance and stability in tissues. Future in vitro studies should also evaluate microanalysis and microscopy of the surface of the suture during the follow-up period.

Conclusion:

Our in vitro findings support the use of Triclosan coated PDS sutures as they show a longer resistance, which is helpful in tendon reconstruction. Contrarily, Triclosan coated Vicryl sutures seem to be less resistant compared to the non-coated Vicryl sutures.

Abbreviations:

N Newton, mm Millimeter, mm/s Millimeter per second

Ethical Approval and Consent to participate: Study design was discussed and clarified, no ethical approval was necessary, all experiments were in vitro

Availability of supporting data: The measurement data is accessible via hyperlink: https://polybox.ethz.ch/index.php/s/6HkXHlnuIFoWqTkhttps://polybox.ethz.ch/index.php/s/6HkXHlnuIFoWqTk

Password: balgrist

Competing interests: None of the authors have any competing interests.

Funding: The Balgrist University Hospital provided the suture material and the infrastructure for measurements and incubation.

Acknowledgements: We thank the Balgrist University Hospital for providing sutures and infrastructure for testing.

Authors' contributions: JWA carried out all the preparation and the measurements of the study and drafted the manuscript. WS designed the study. BE did the statistical analysis and analyzed the mechanical properties. GF and IMA corrected and helped with the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1 metallic cylinder 40mm in diameter

Figure 2 Incubation of sutures in polyethylene tube containing 50 ml of a standard testing solution

Figure 3 Fixation of loops in material testing machine

Figure 4 Load to failure

Figure 5 Stiffness after cycling loading

Figure 6 Strain after cycling loading

Tables

Table 1 Three different absorbable sutures were tested at four time points.

Table 2 p-Value: Stiffness after cycling loading

Table 3 p-Value: Strain after cycling loading

Table 4 Load to failure

Table 1: Three different absorbable sutures were tested at four time points.

suture	**Comparative pairing**	
Monocryl	Ethicon®Monocryl™ Strength 3-0	Ethicon®Monocryl™Plus Strength 3-0
PDS	Ethicon®PDS™ Strength 0	Ethicon®PDS™Plus Strength 0
Vicryl	Ethicon®Vicryl™ Strength 1	Ethicon®Vicryl™Plus Strength 1

Table 2:
p-Value: Stiffness after cycling loading

Stiffness after cyclic loading	Day			
	0	14	28	42
PDS 0 vs PDS 0 plus	0.6557	0.0537	0.0312	0.3299
Vicryl 1 vs Vicryl 1 plus	0.0114	0.013	*	*
Monocryl 3-0 vs Monocryl 3-0 plus	0.0127	0.0963	*	*

Samples tested on Day 0: 4/5 PDS 0, 5/5 PDS 0 plus, 4/5 Vicryl 1, 5/5 Vicryl 1 plus, 4/5 Monocryl 3-0 and 5/5 Monocryl 3-0 plus
Day 14: 5/5 PDS 0, 5/5 PDS 0 plus, 5/5 Vicryl 1, 5/5 Vicryl 1 plus, 5/5 Monocryl 3-0 and 5/5 Monocryl 3-0 plus
Day 28: 4/5 PDS 0, 5/5 PDS 0 plus, 1/5 Vicryl 1, 2/5 Vicryl 1 plus, 0/5 Monocryl 3-0 and 0/5 Monocryl 3-0 plus
Day 42: 4/5 PDS 0, 4/5 PDS 0 plus, 0/5 Vicryl 1, 0/5 Vicryl 1 plus, 0/5 Monocryl 3-0 and 0/5 Monocryl 3-0 plus

Table 3

p-Value: Strain after cycling loading

Strain after cyclic loading	Day			
	0	14	28	42
PDS0 vs PDS0+	0.6495	0.1616	0.655	0.9604
Vicryl1 vs Vicryl1+	0.3488	0.1936	*	*
Monocryl 3-0 vs Monocryl 3-0+	0.4661	0.645	*	*

*not enough samples for statistical evaluation

Samples tested on Day 0: 5/5 PDS 0, 4/5 PDS 0 plus, 4/5 Vicryl 1, 5/5 Vicryl 1 plus, 4/5 Monocryl 3-0 and 5/5 Monocryl 3-0 plus

Day 14: 4/5 PDS 0, 5/5 PDS 0 plus, 4/5 Vicryl 1, 5/5 Vicryl 1 plus, 4/5 Monocryl 3-0 and 5/5 Monocryl 3-0 plus

Day 28: 4/5 PDS 0, 5/5 PDS 0 plus, 1/5 Vicryl 1, 1/5 Vicryl 1 plus, 0/5 Monocryl 3-0 and 0/5 Monocryl 3-0 plus

Day 42: 3/5 PDS 0, 4/5 PDS 0 plus, 0/5 Vicryl 1, 0/5 Vicryl 1 plus, 0/5 Monocryl 3-0 and 0/5 Monocryl 3-0 plus

Table 4 Load to failure

Suture	Day 0, Force (N)	p-value	Day 14, Force (N)	p-value	% of force of comparative suture	Day 28, Force (N)	p-value	% of force of comparative suture	Day 42, Force (N)	p-value
Vicryl 1	136.2 (127-145)	p=0.7364	128.8 (121-138)	p=0.033	87.7	54.52 (41.4-66.2)	p=0.032	78.7	5.98 (0.81-13.2)	p=0.952
Vicryl 1 plus	133.2 (106-148)		113 (102-128)			42.88 (41.7-50.5)			6.156 (0.8-8.37)	
PDS 0	72.86 (42.2-90.3)	p=0.6231	96.7 (92.9-101)	p=0.916		85.3 (78.6-90.9)	p=0.039	90	57.66 (44.7-65.1)	p=0.985
PDS 0 plus	78.58 (64.1-103)		96.36 (91.1-100)			94.7 (87.7-103)			57.74 (53.2-62.9)	
Monocryl 3-0	48.28 (44.2-58.4)	p=0.7379	15.3 (13.7-17.7)	p=0.282		1.283 (1.05-1.53)	p=0.014*		n.a.	
Monocryl 3-0 plus	49.84 (41.1-59.8)		18.04 (11.8-25.4)			2.12 (1.88-2.38)			n.a.	

*not enough samples for statistical evaluation
Comparative sutures: Vicryl 1 vs Vicryl 1 plus; PDS 0 vs PDS 0 plus; Monocryl 3-0 vs Monocryl 3-0 plus
Samples tested on Day 0: 5/5 PDS 0, 5/5 PDS 0 plus, 5/5 Vicryl 1, 5/5 Vicryl 1 plus, 5/5 Monocryl 3-0 and 5/5 Monocryl 3-0 plus
Day 14: 5/5 PDS 0, 5/5 PDS 0 plus, 5/5 Vicryl 1, 5/5 Vicryl 1 plus, 5/5 Monocryl 3-0 and 5/5 Monocryl 3-0 plus
Day 28: 5/5 PDS 0, 5/5 PDS 0 plus, 5/5 Vicryl 1, 5/5 Vicryl 1 plus, 3/5 Monocryl 3-0 and 3/5 Monocryl 3-0 plus
Day 42: 5/5 PDS 0, 5/5 PDS 0 plus, 5/5 Vicryl 1, 5/5 Vicryl 1 plus, 0/5 Monocryl 3-0 and 0/5 Monocryl 3-0 plus

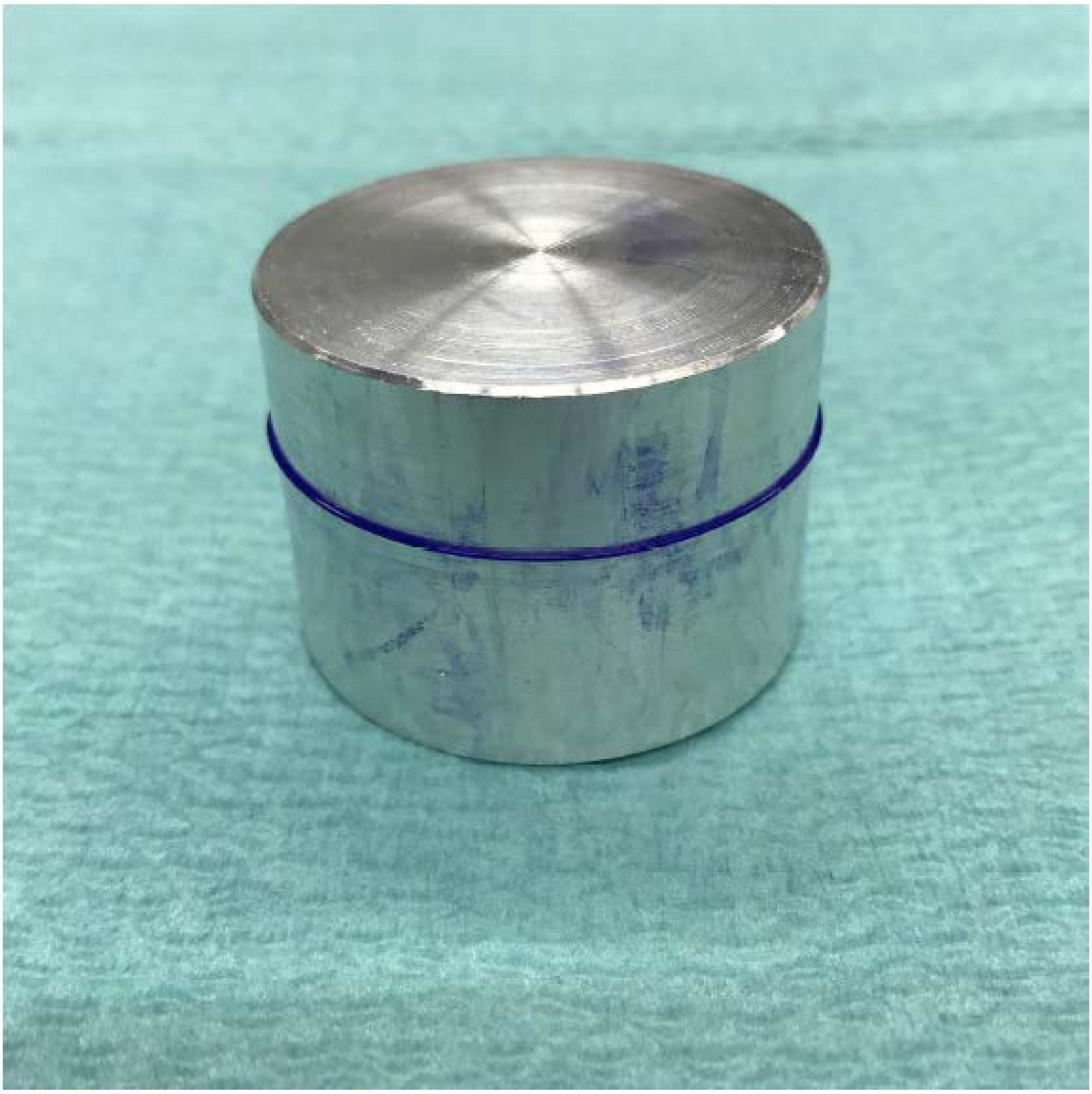

Fig. 1 metallic cylinder 40mm in diameter

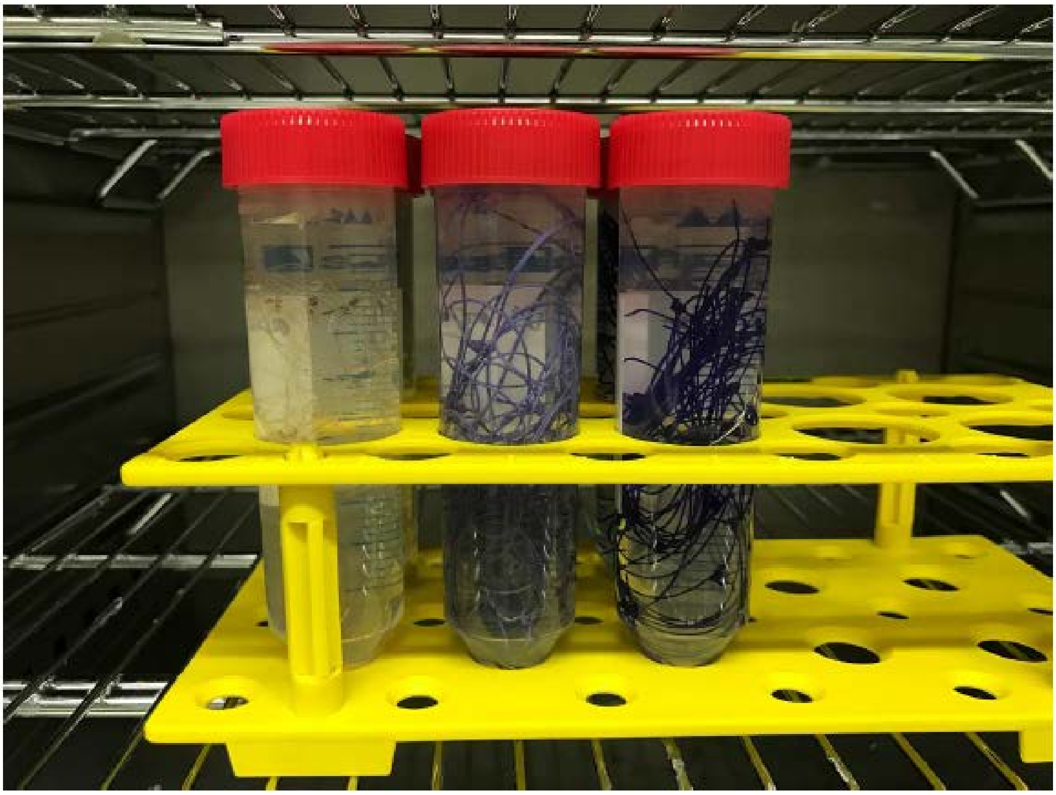

Fig. 2 Incubation of sutures in polyethylene tube containing 50 ml of a standard testing solution

Fig. 3 Fixation of loops in material testing machine

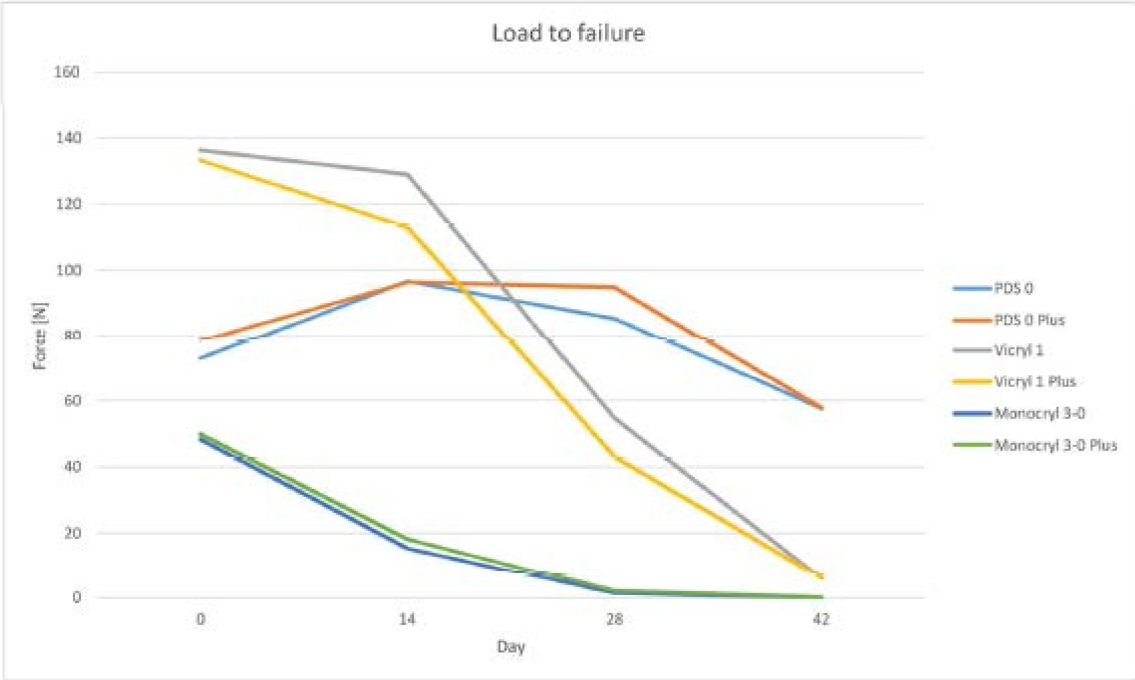

Fig. 4 Load to failure

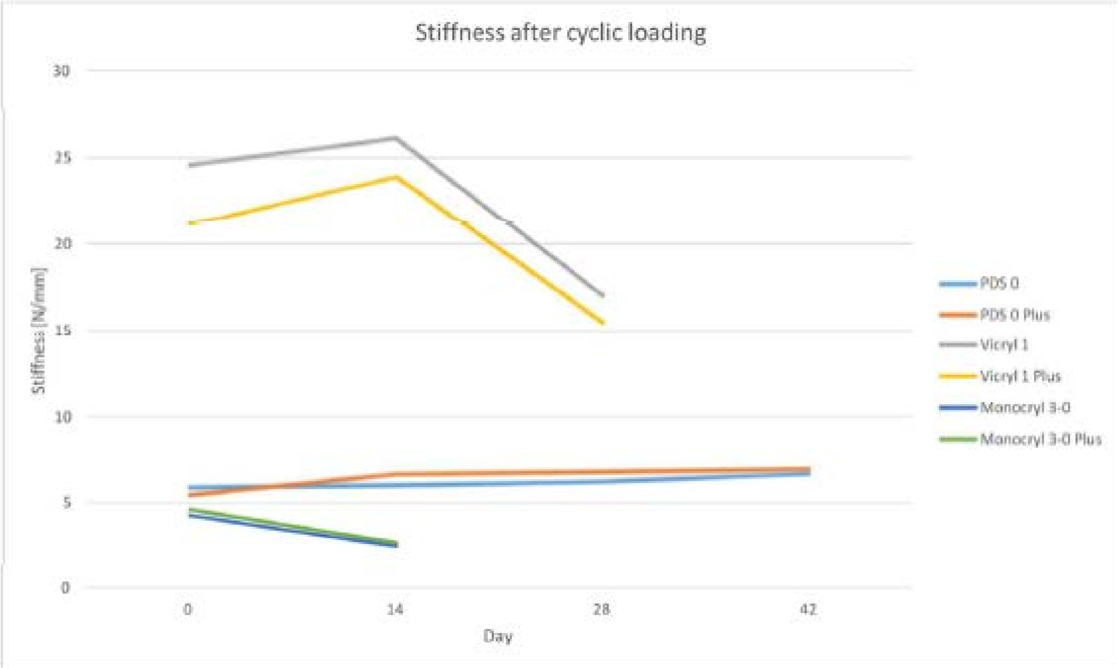

Fig. 5 Stiffness after cycling loading

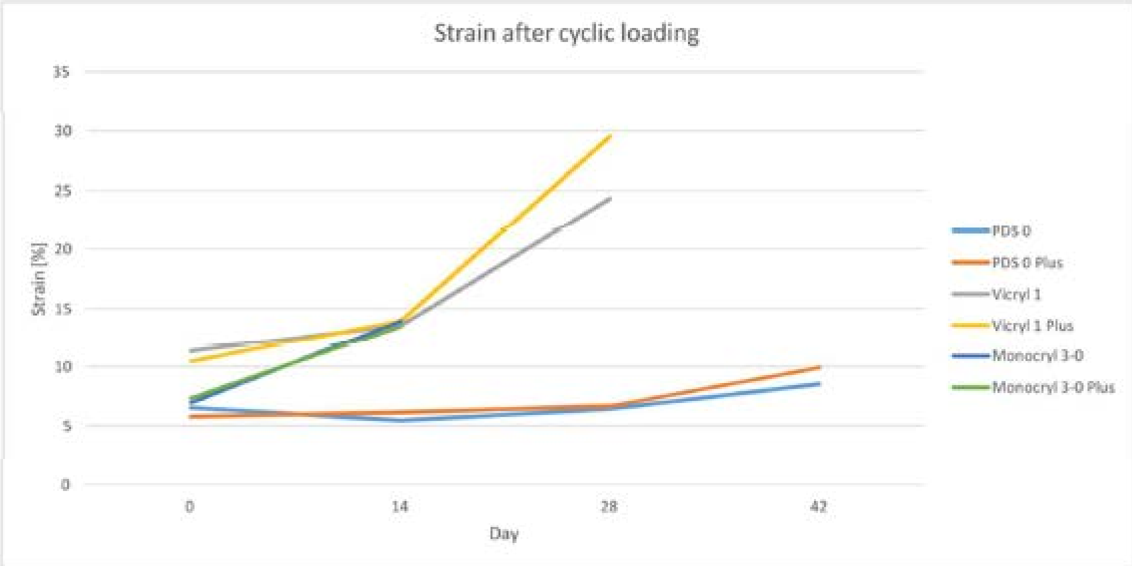

Fig. 6 Strain after Cycling Loading